The UV spectral window: new means to constrain the stellar populations of early-type galaxies

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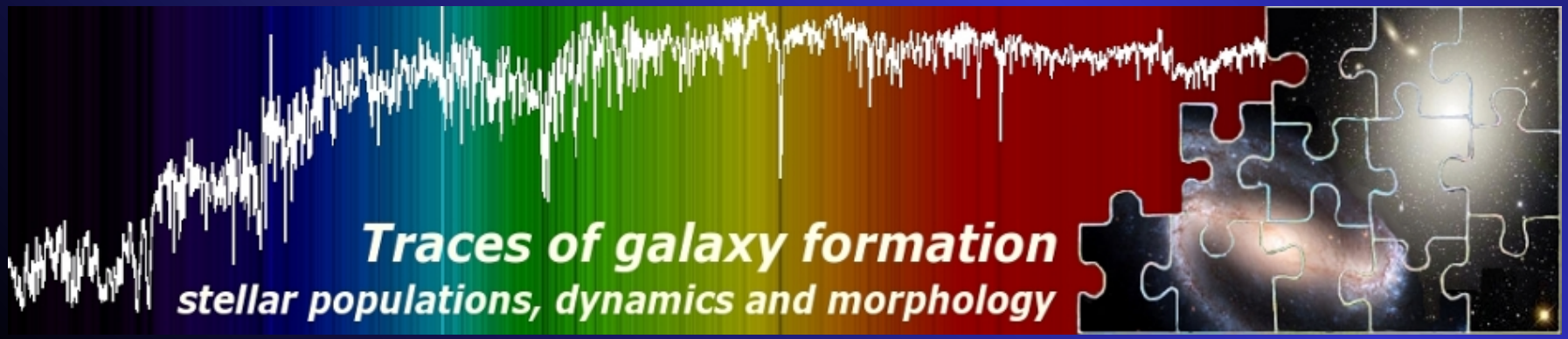
Early Data Release and Scientific Exploitation of the J-PLUS Survey

Teruel, 2-3 October 2017



Early-Type galaxies

~ 10-20% of the galaxies but contain ~70% of the stellar mass of the Universe.

Are thought to be the end-products within a hierarchical galaxy formation framework. In fact they do pose a major challenge to these models

To be constrained by looking at the stellar populations resulting from their Star Formation Histories

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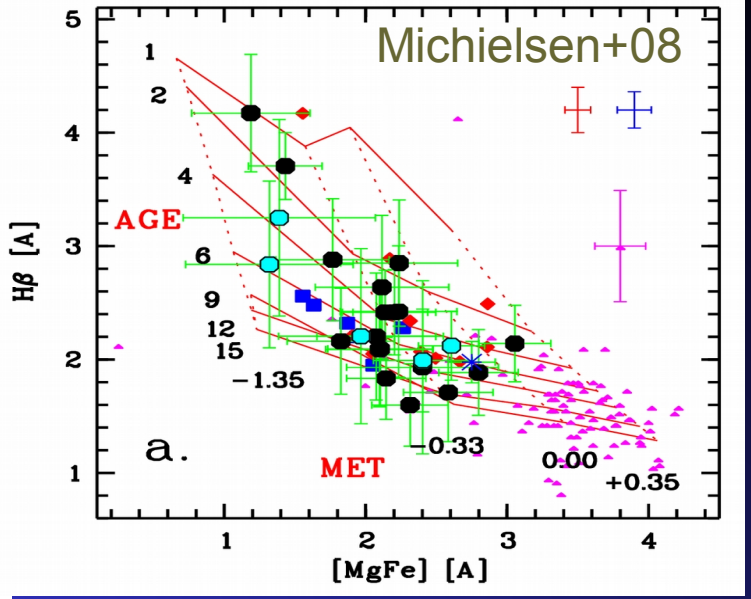
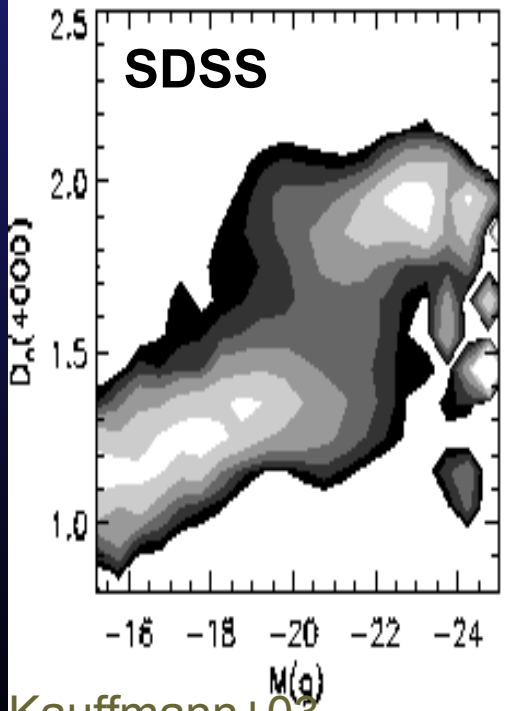
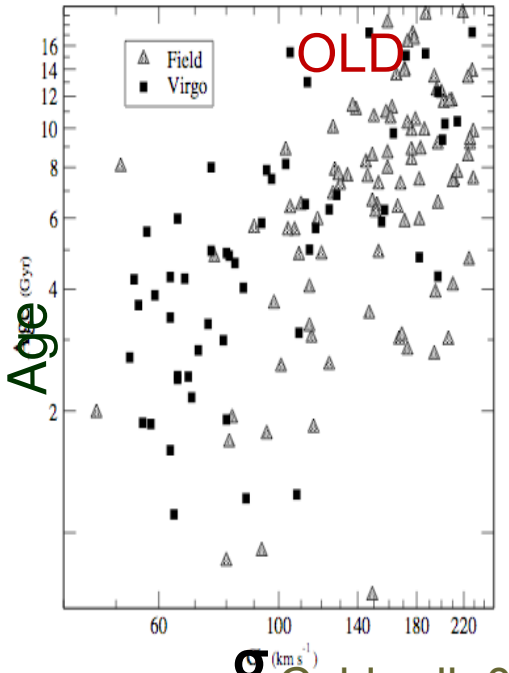
Stellar populations: results from detailed spectroscopic studies (mostly from the optical range)

Massive ETGs older and more metal-rich than their lower mass counterparts (downsizing)



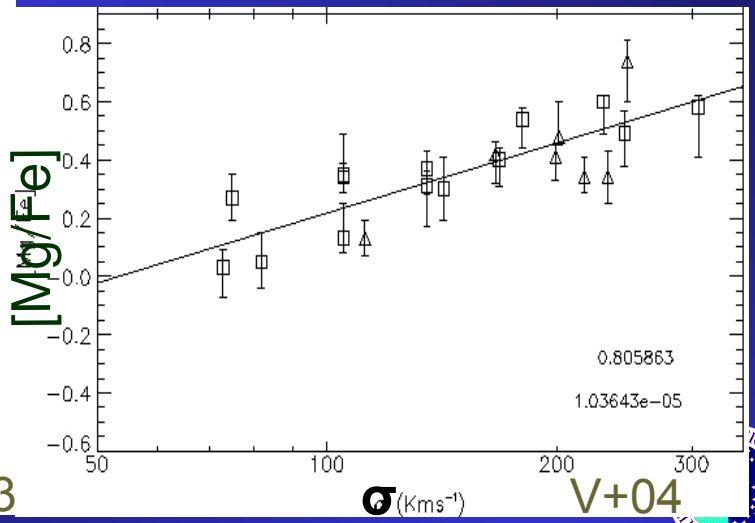


Kauffmann+03



Caldwell+03

and not only formed the bulk of their stars earlier but faster (<1Gyr)



V+04

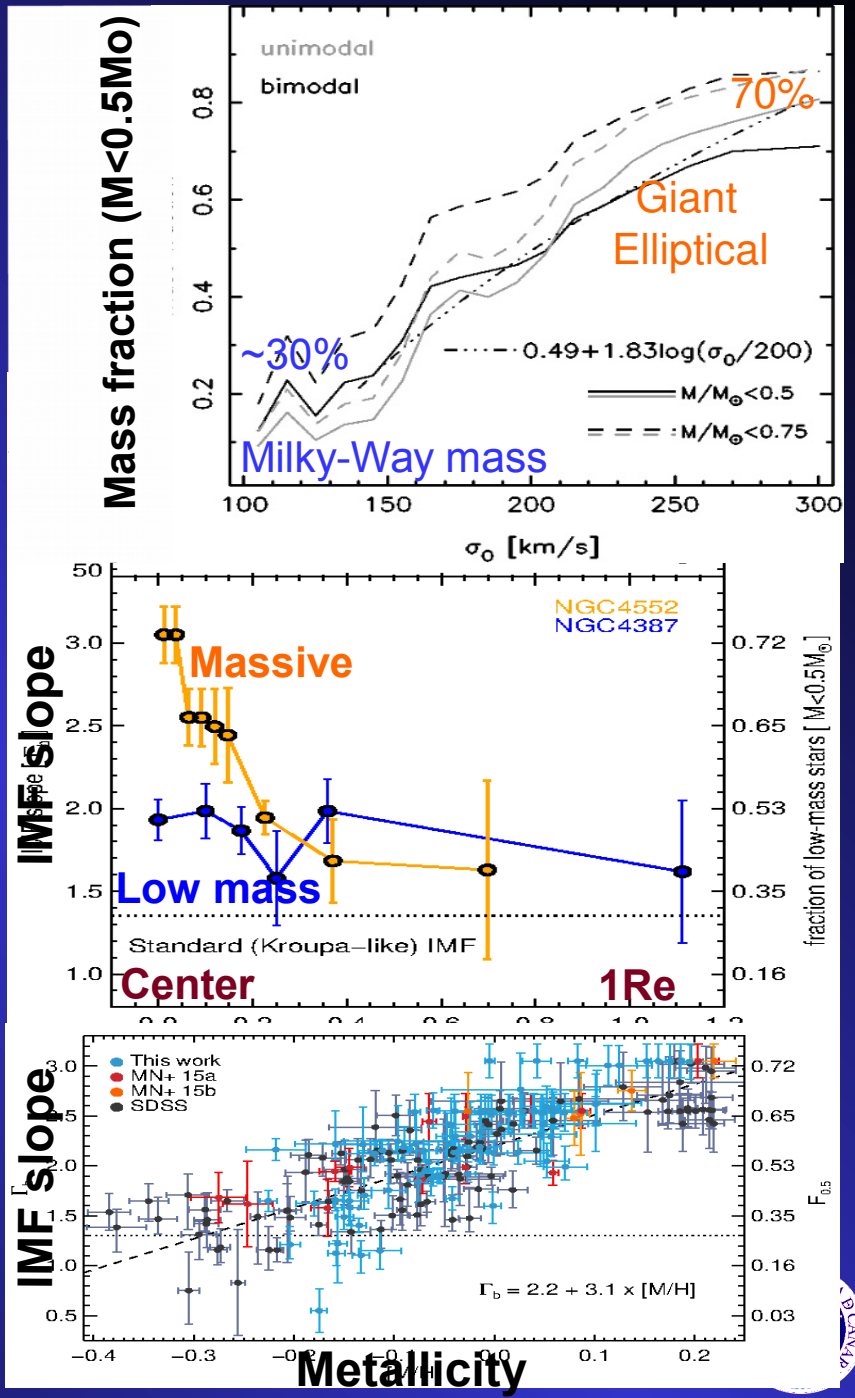
and the IMF is no longer universal...

Varies with galaxy mass: massive ETGs are enhance in low-mass dwarfs (<0.5Mo), i.e. IMF slope - σ relation (Cenarro+03; Ferreras+13; LaBarbera+13)

Varies locally within massive galaxies: bottom-heavy in the center & MW-like at ~1Re (Martín-Navarro+15a;LaBarbera+16[a])

Correlates with metallicity: both global and locally (Martín-Navarro+15b)

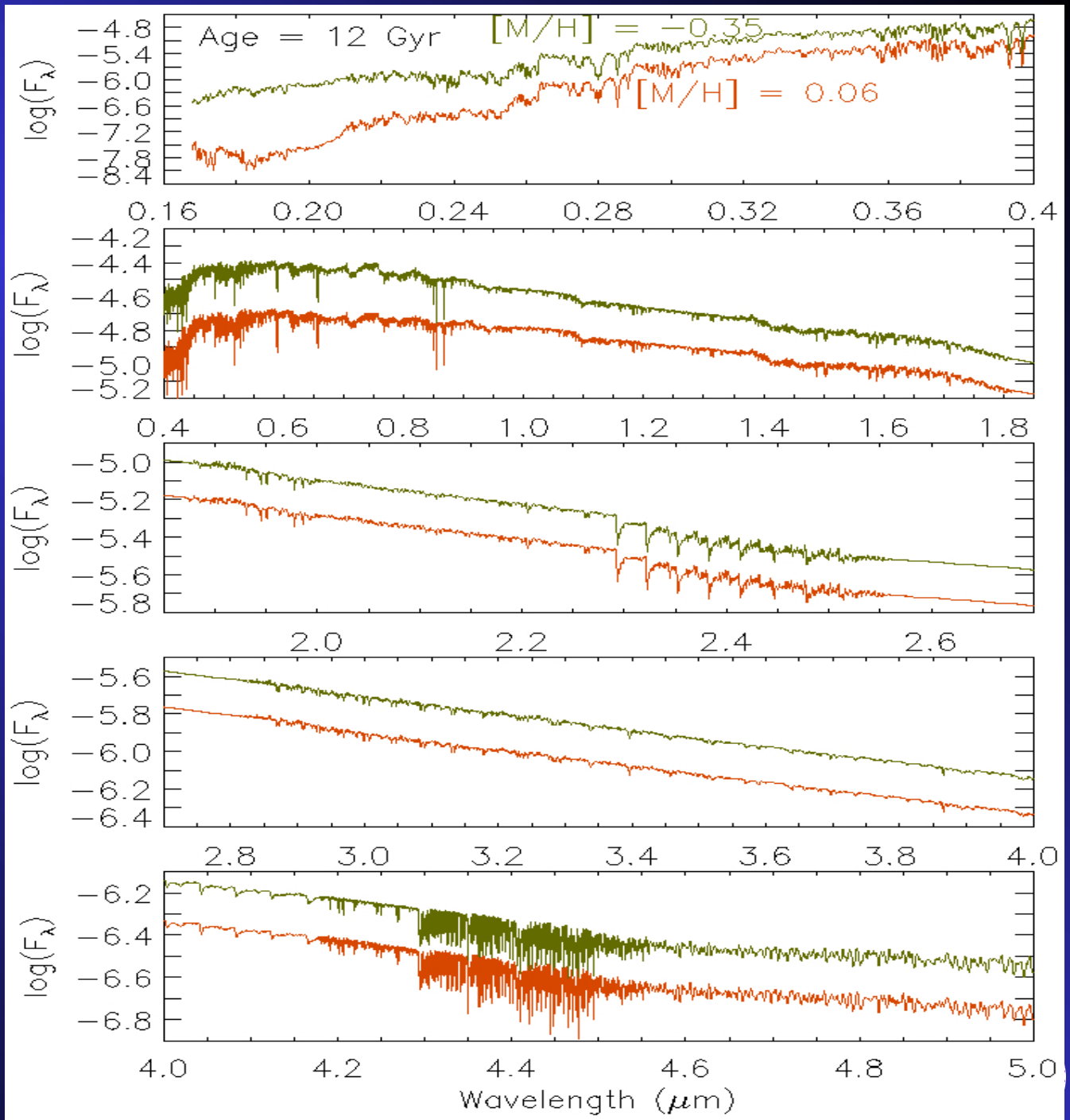
It varies with time: from top to bottom-heavy (V+96,97;Weidner+13;Ferreras+15)



Extended E-MILES models

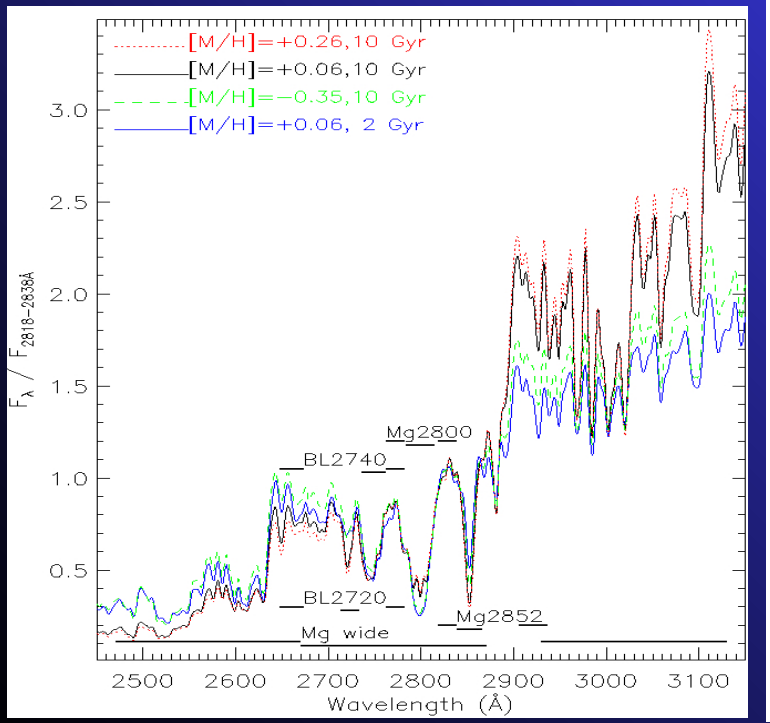
- Based on extensive fully empirical stellar spectral libraries (NGSL, MILES, Indo-US, CaT, IRTF)
- Spectral range: 0.17-5μ
- Resolution: FWHM~2.5Å (λ<0.9μ)
  σ ~ 60 Kms^{-1} (λ>0.9μ)

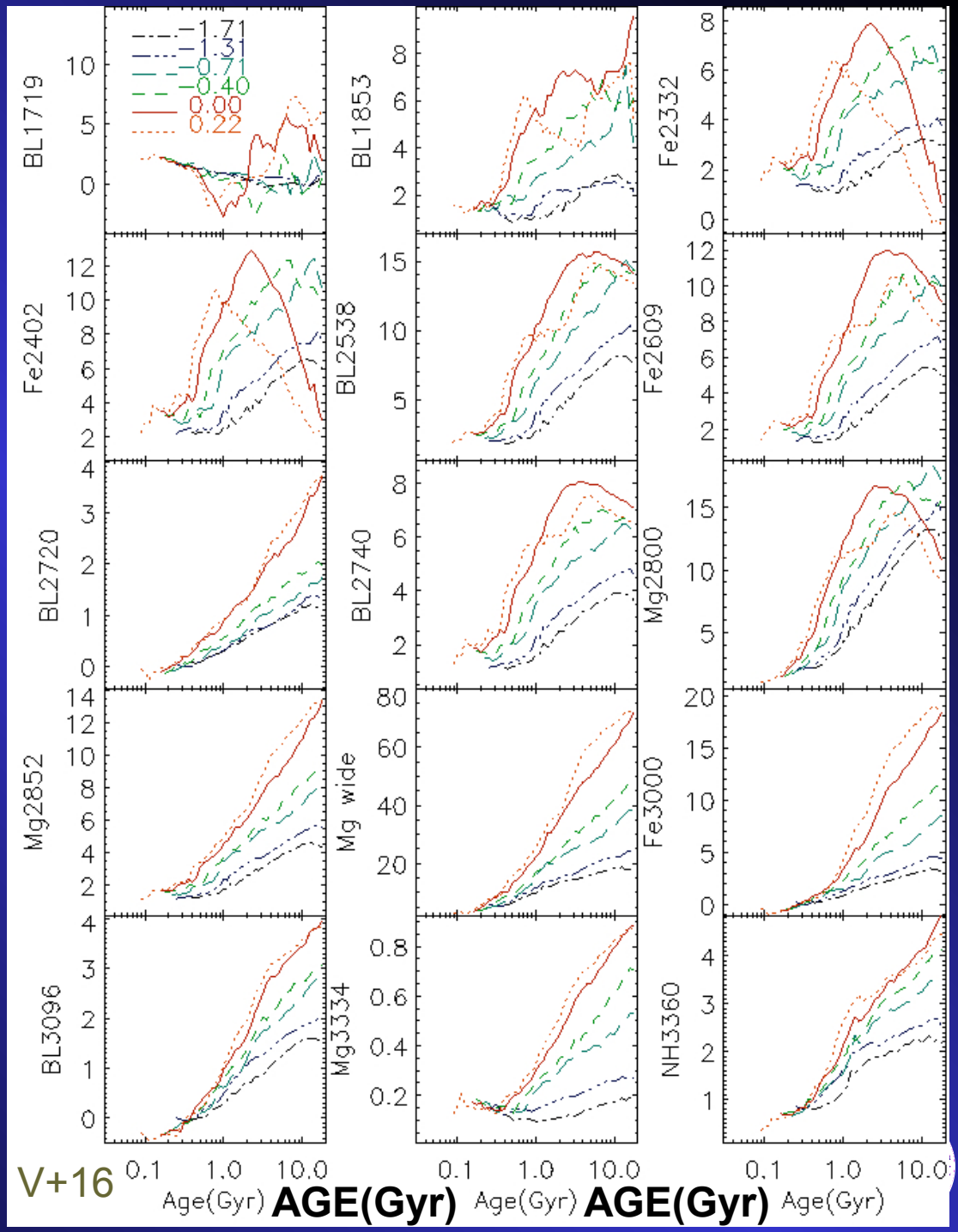
V+16



UV line-strength indices

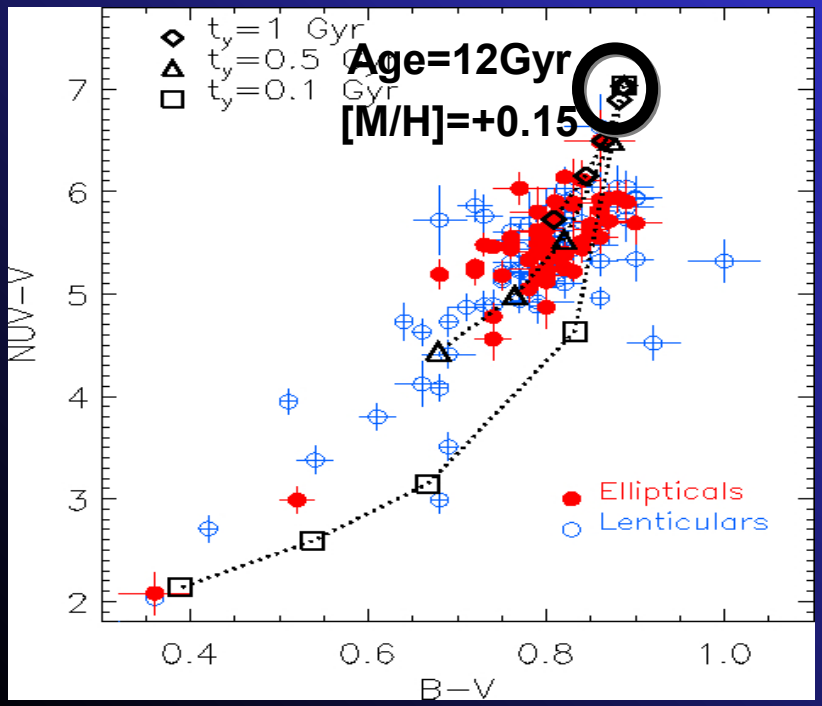
- Redder indices, e.g. Fe3000 strengthen with age much faster than in the optical
- Some (not all) indices below 3000Å peak around 2-3 Gyr (e.g., Mg2800, BL2402) for metal-rich stellar populations
- Varying behaviours offer new means to constrain the SFHs!





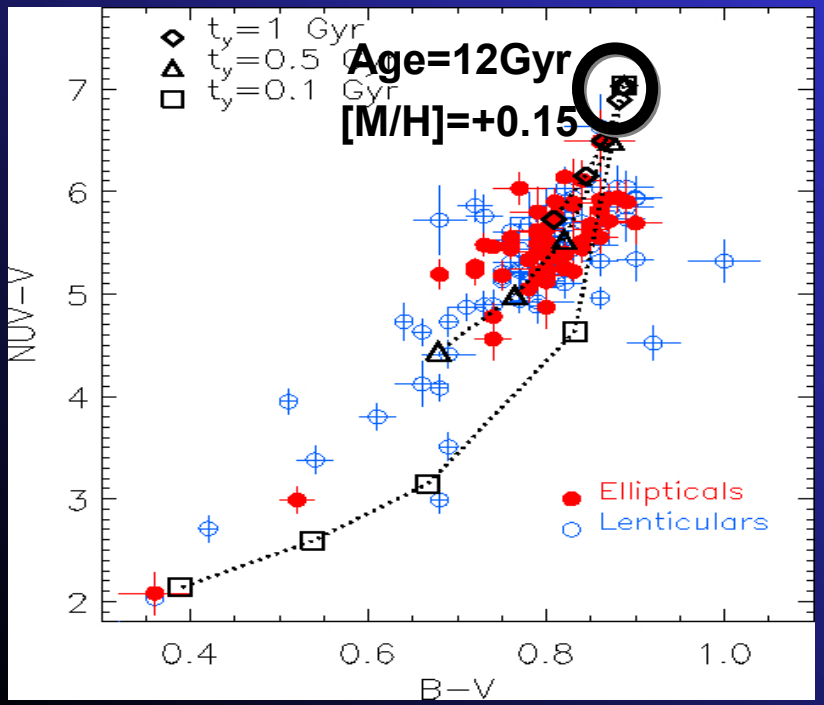
What about the UV?

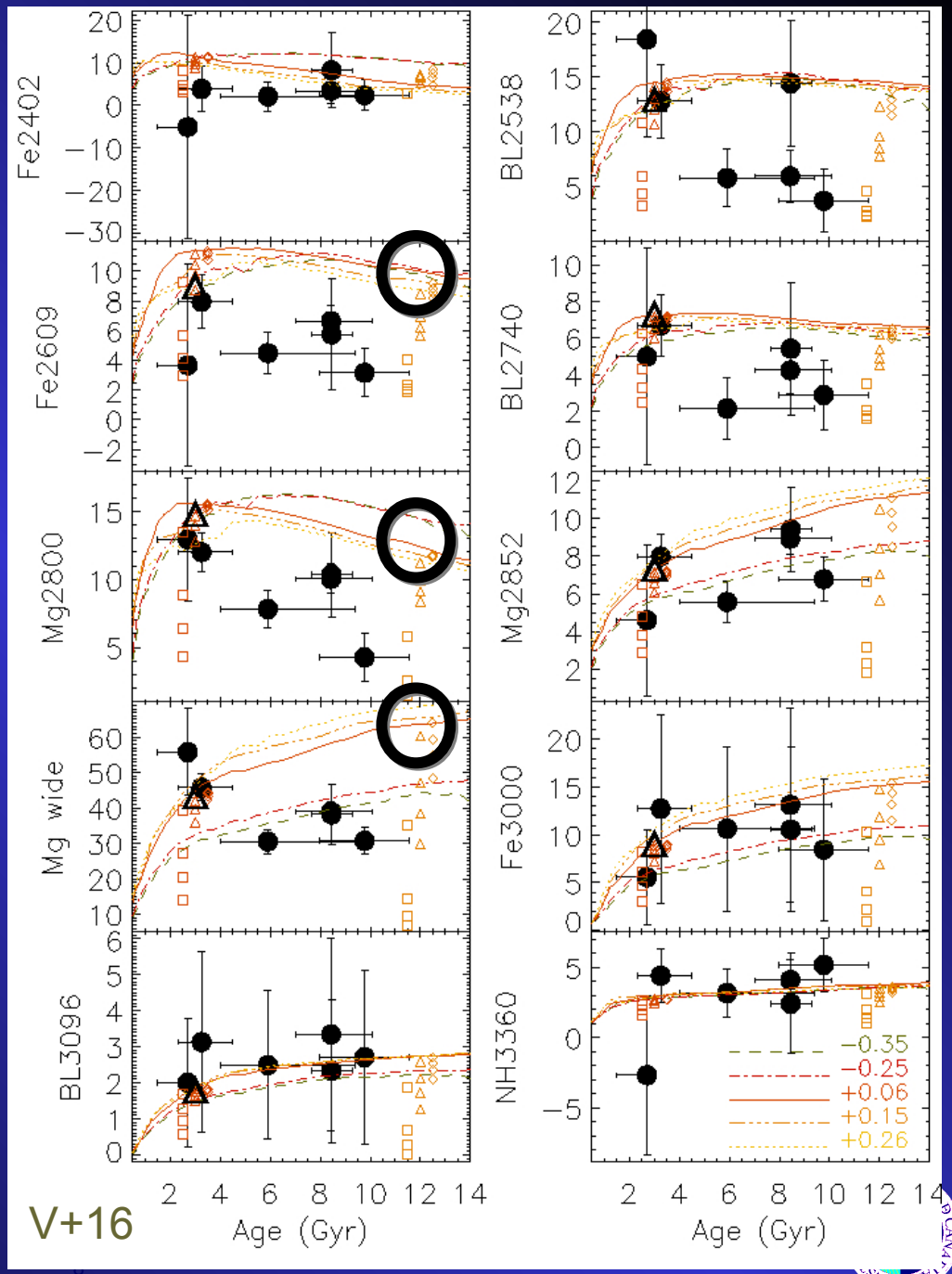
NUV colours cannot be fitted with OLD and METAL-RICH stellar populations



What about the UV?

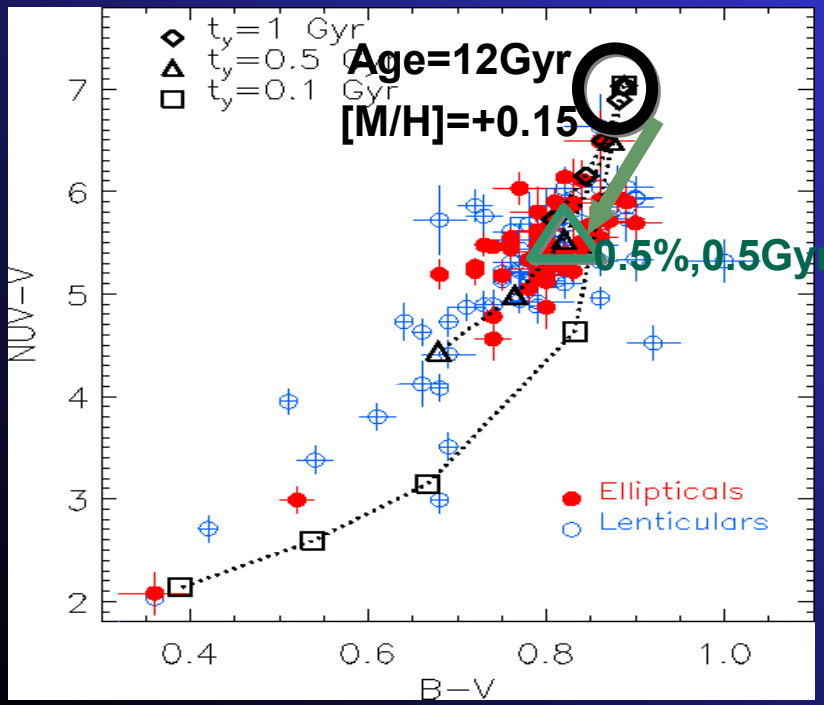
NUV colours cannot be fitted with OLD and METAL-RICH stellar populations, nor the NUV line-strengths

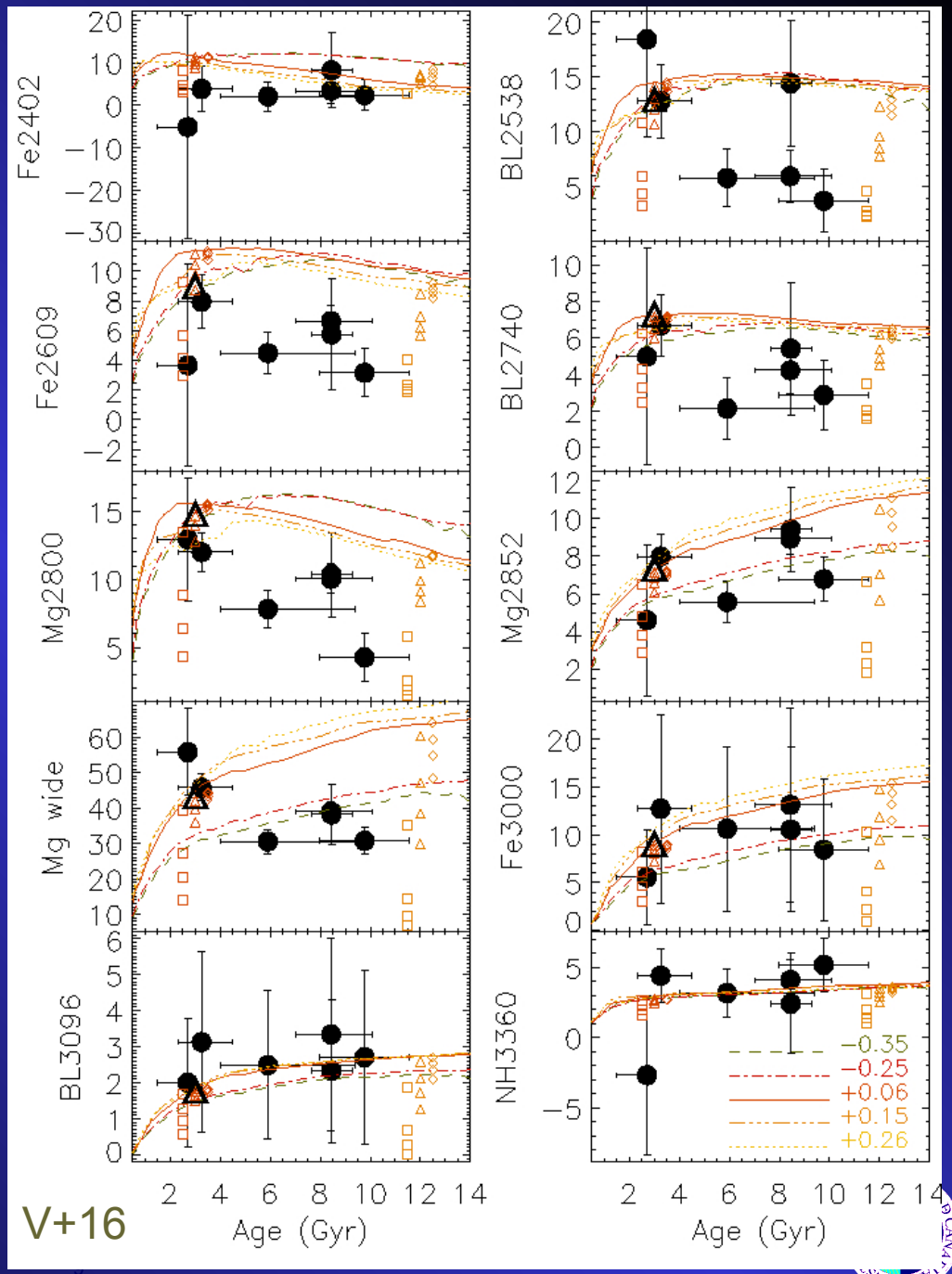




What about the UV?

- **NUV colours & line indices show evidence of 0.1-0.5% mass fraction contribution of 0.1-0.5Gyr component on the top of the old population**





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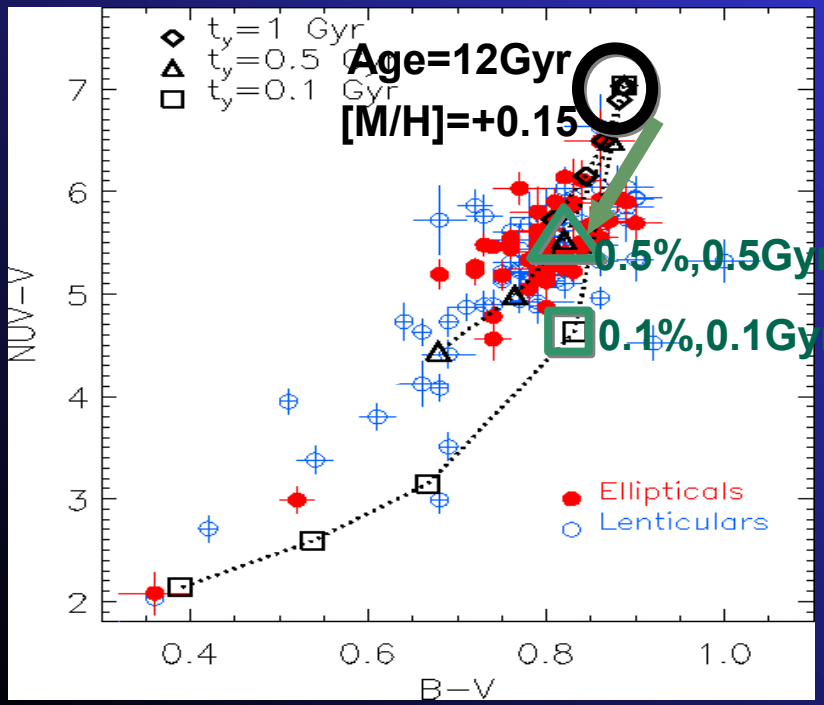
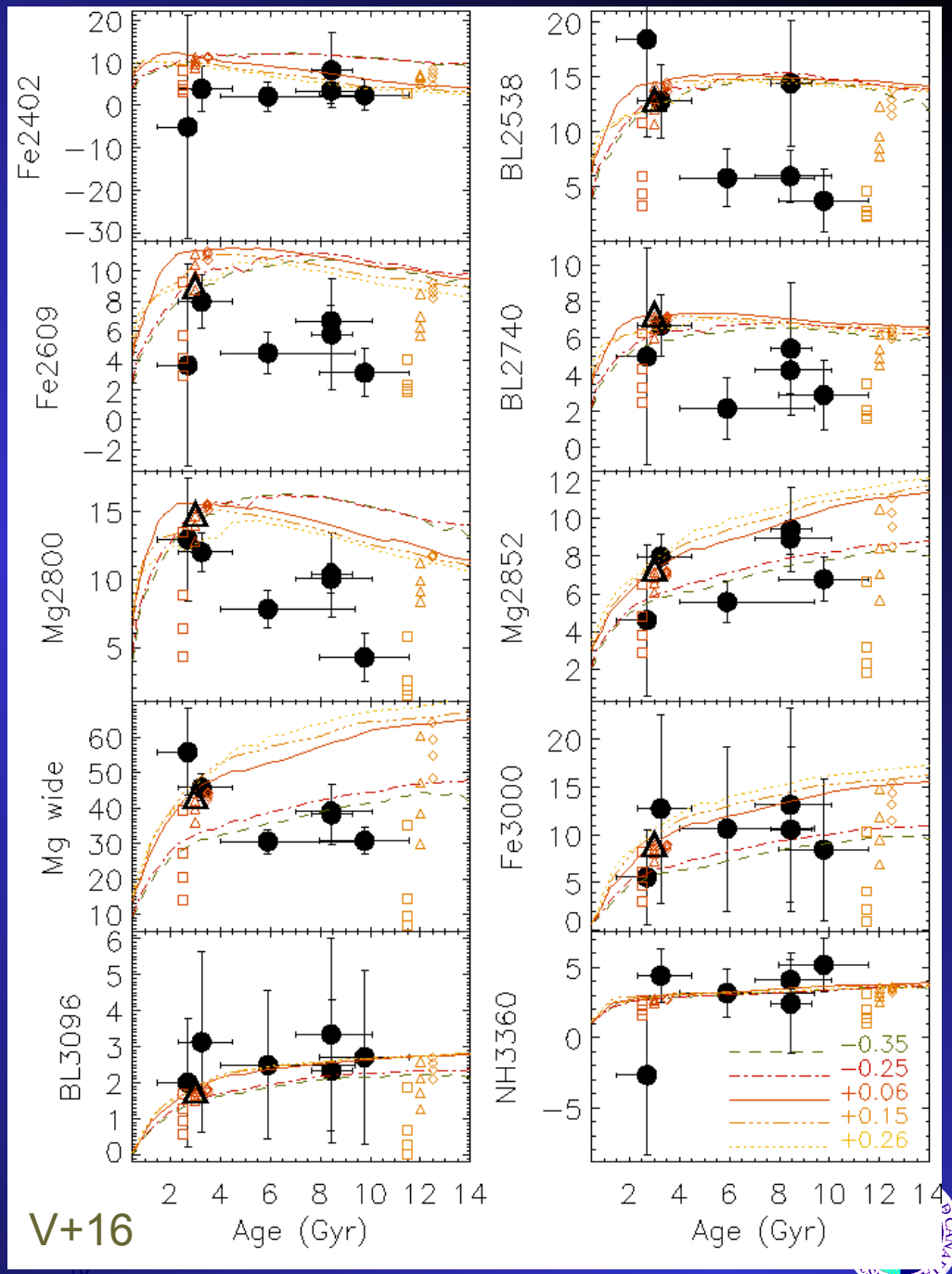
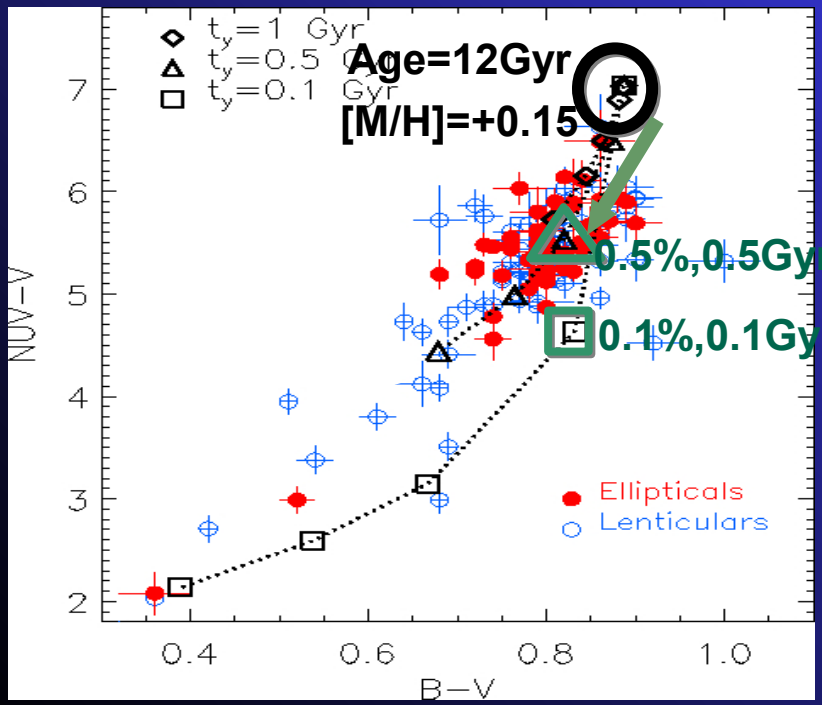
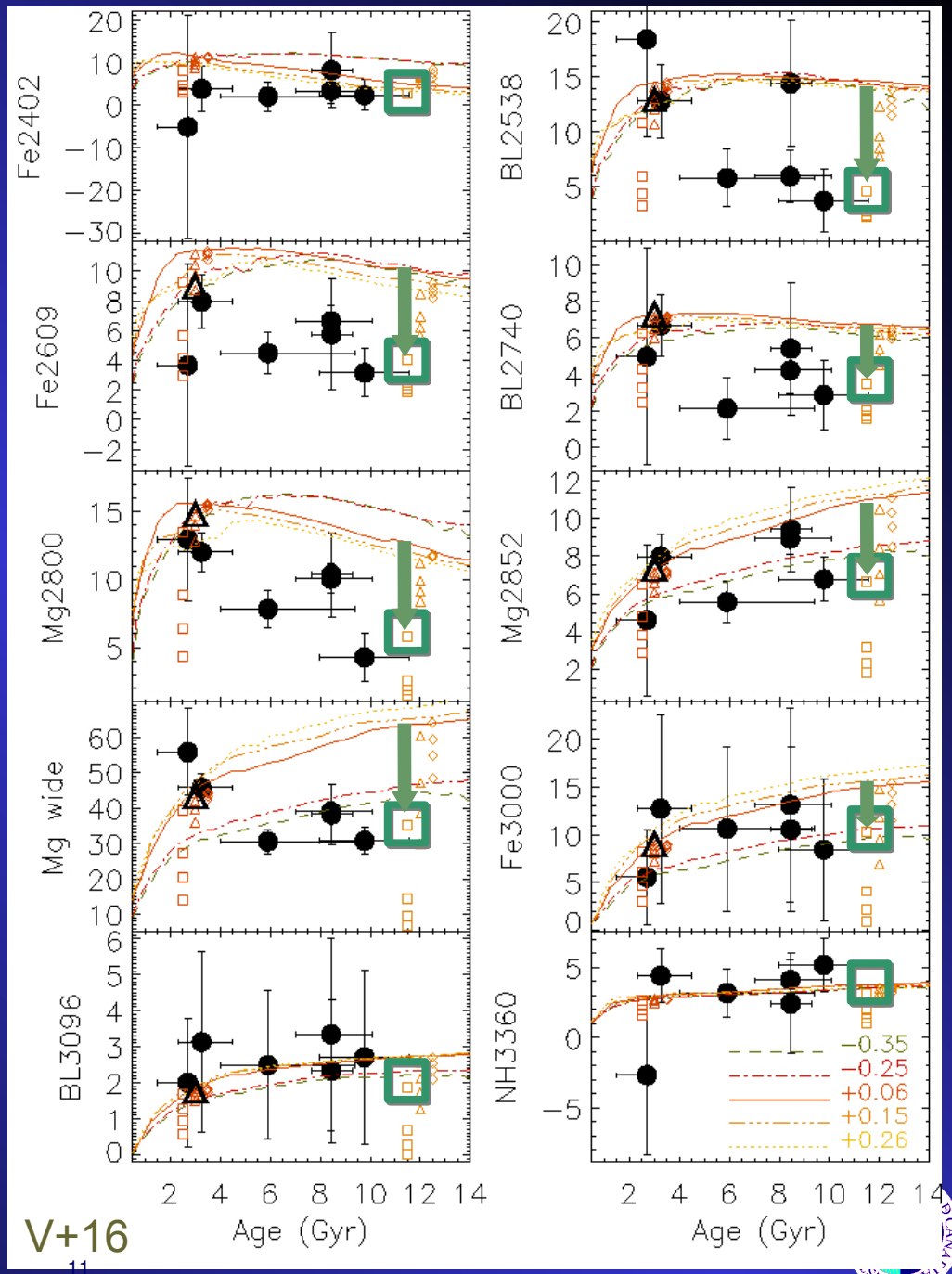




What about the UV?

- NUV colours & line indices show evidence of 0.1-0.5% mass fraction contribution of 0.1-0.5Gyr component on the top of the old population
- These tiny contributions have little impact on the visible: consistent with optical and near-IR results !!!

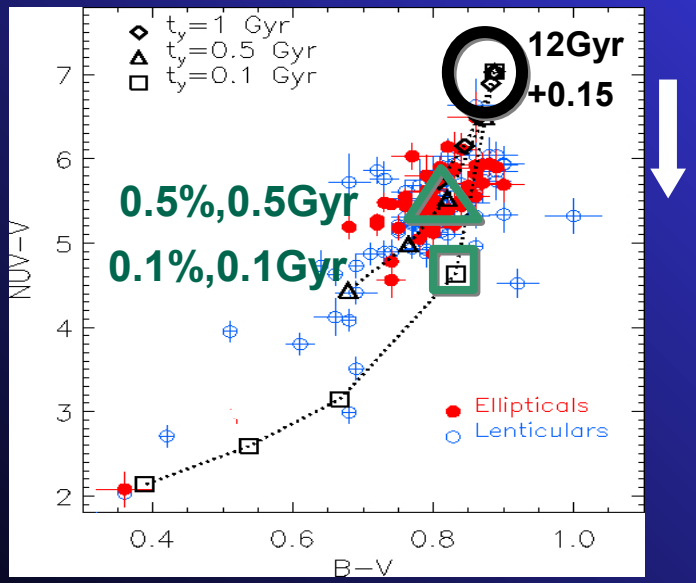




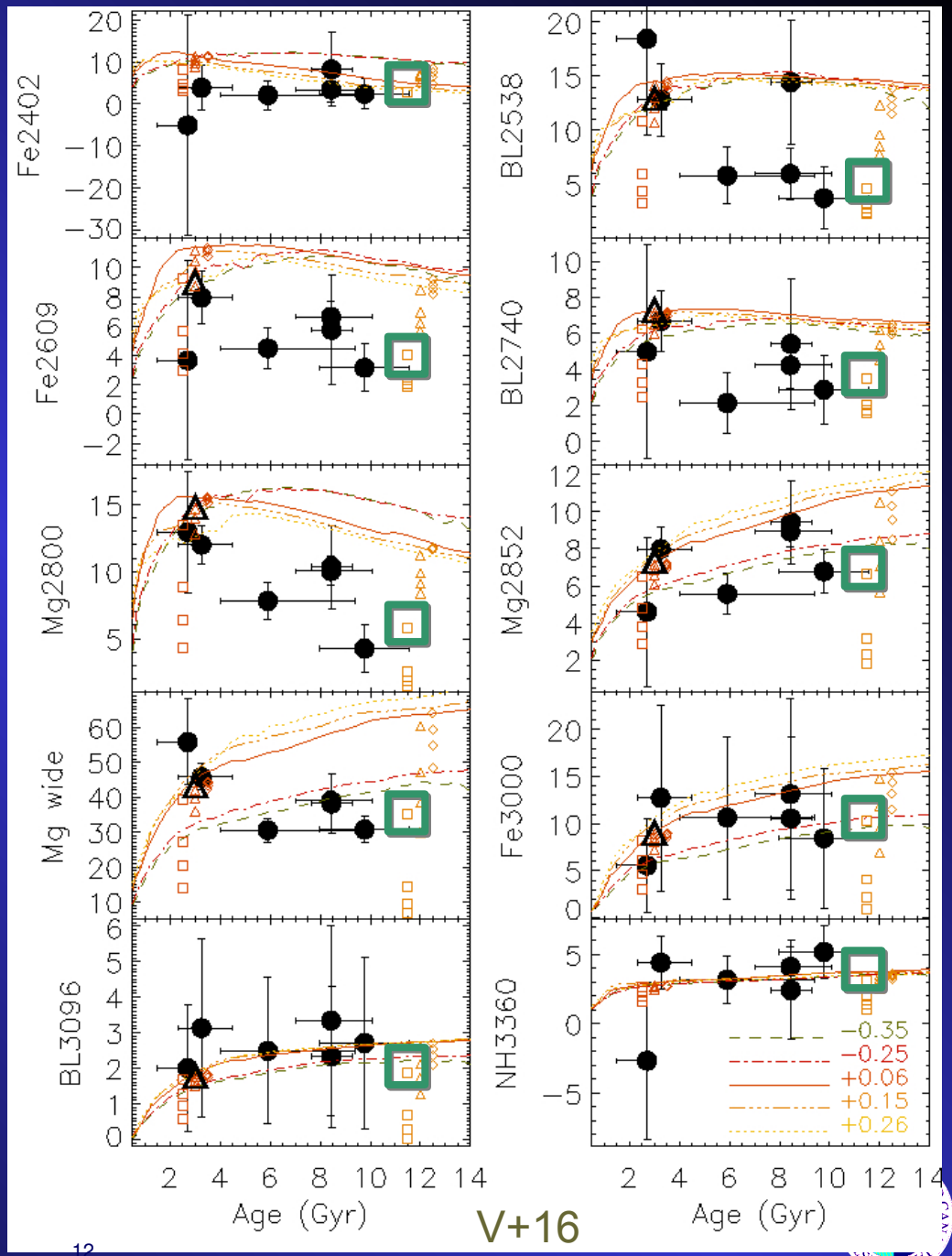
V+16

What about the UV?

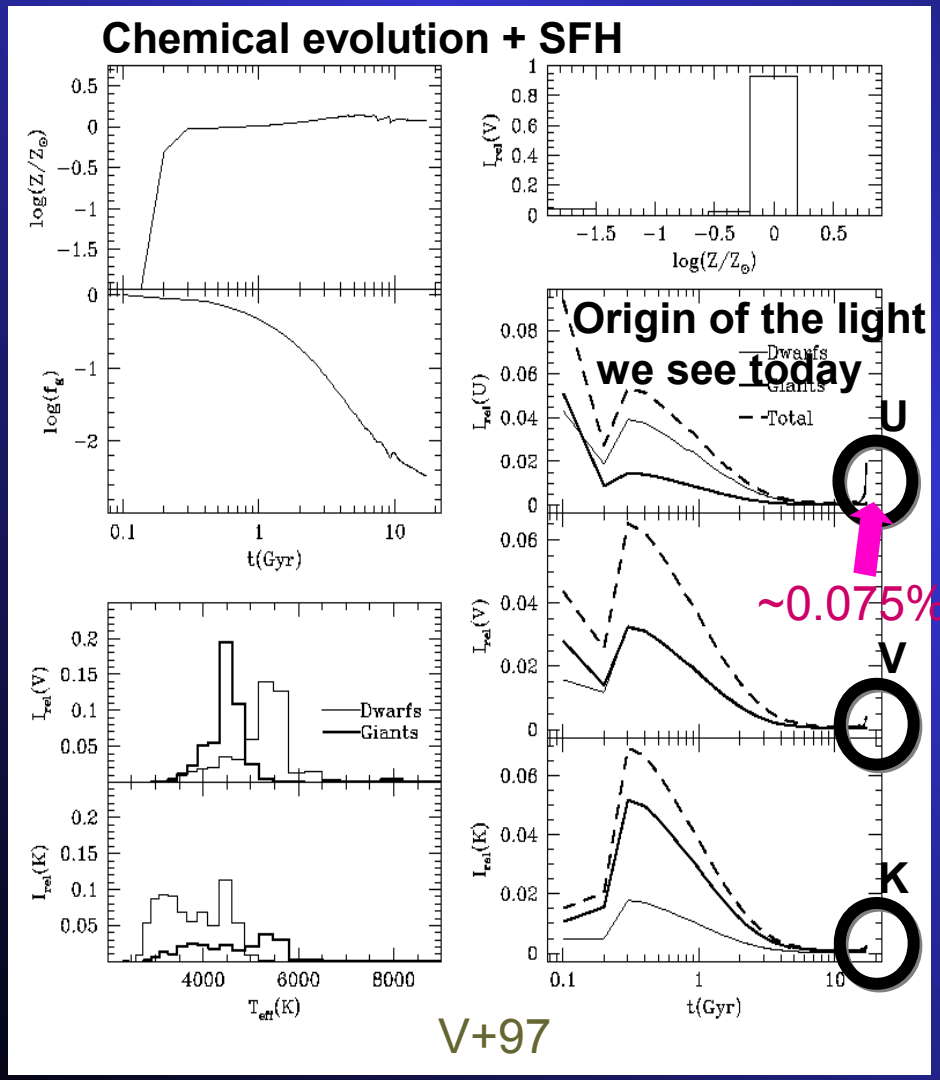
- Both NUV colours & line-strengths show evidence of 0.1-0.5% mass fraction contribution of a 0.1-0.5Gyr component on the top of the old population
- These tiny contributions have little impact on the visible
- ~1Gyr component ruled out!



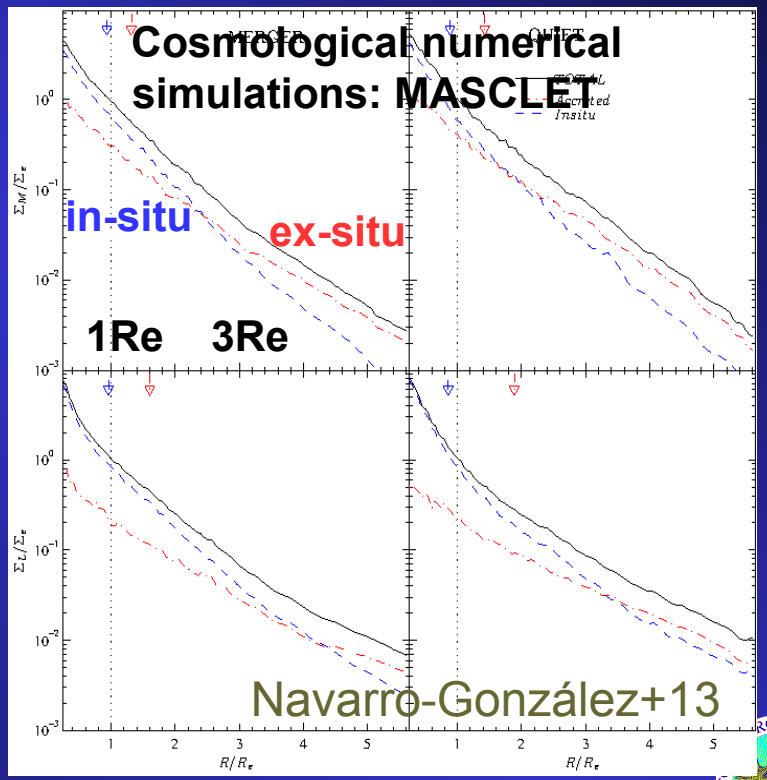
- Fully consistent results with the optical and near-IR !!!



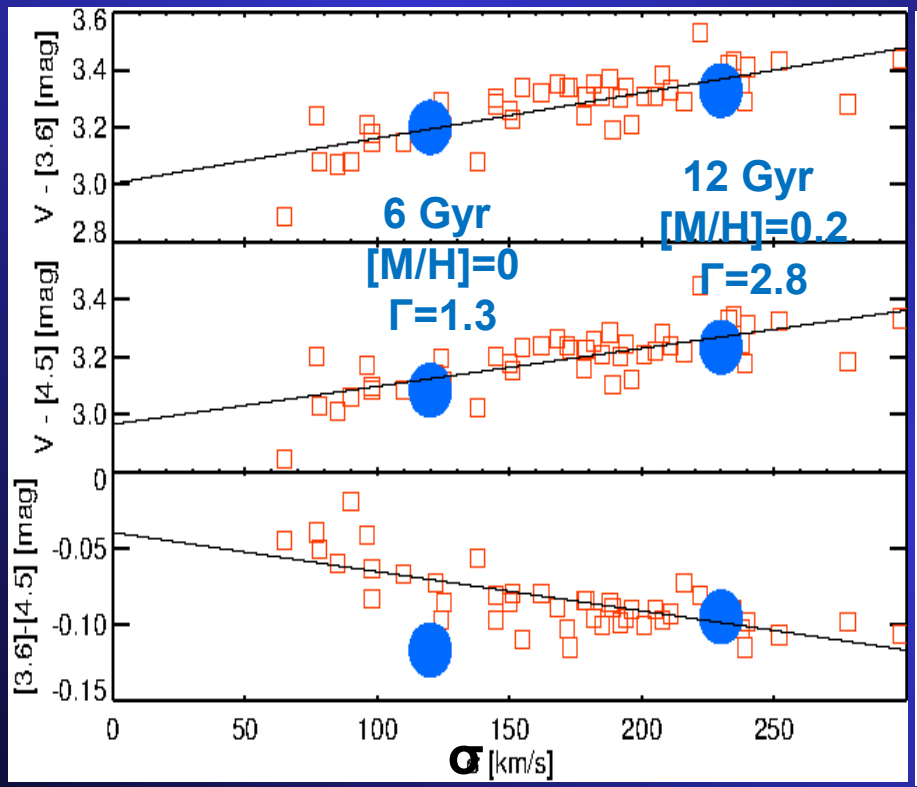
This result is fully consistent with residual SF within a passive evolution scenario with "no ex-situ" contributions

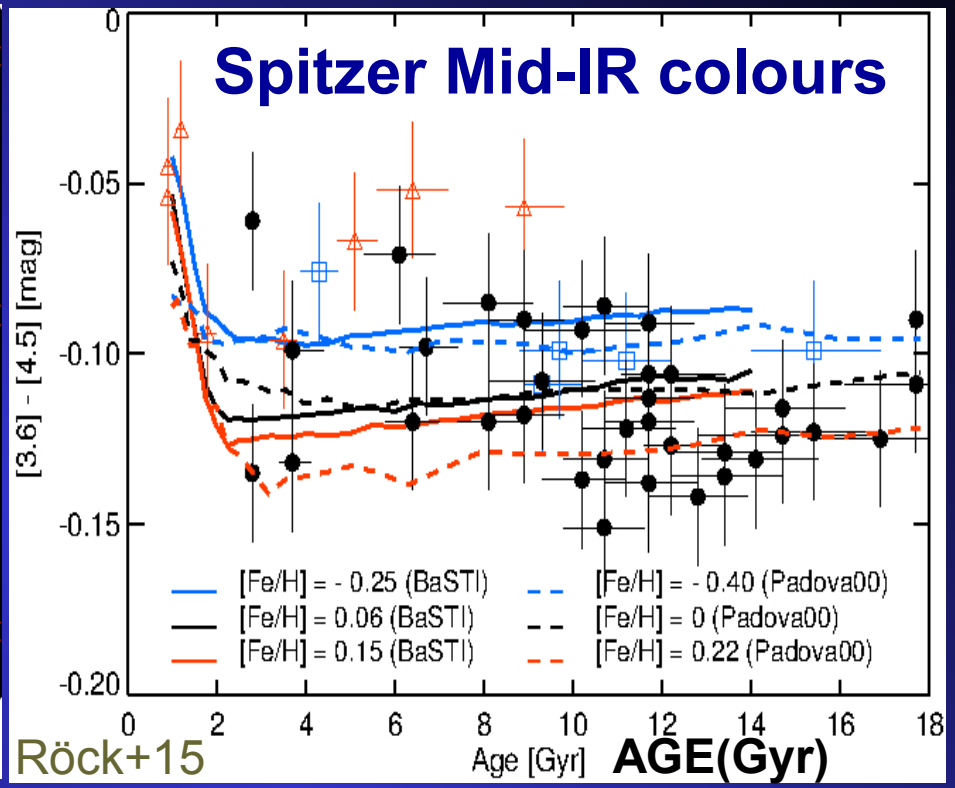


Cosmological numerical simulations: major "in-situ" contribution within < 1-3 Re



Are these results consistent with the Near-IR?





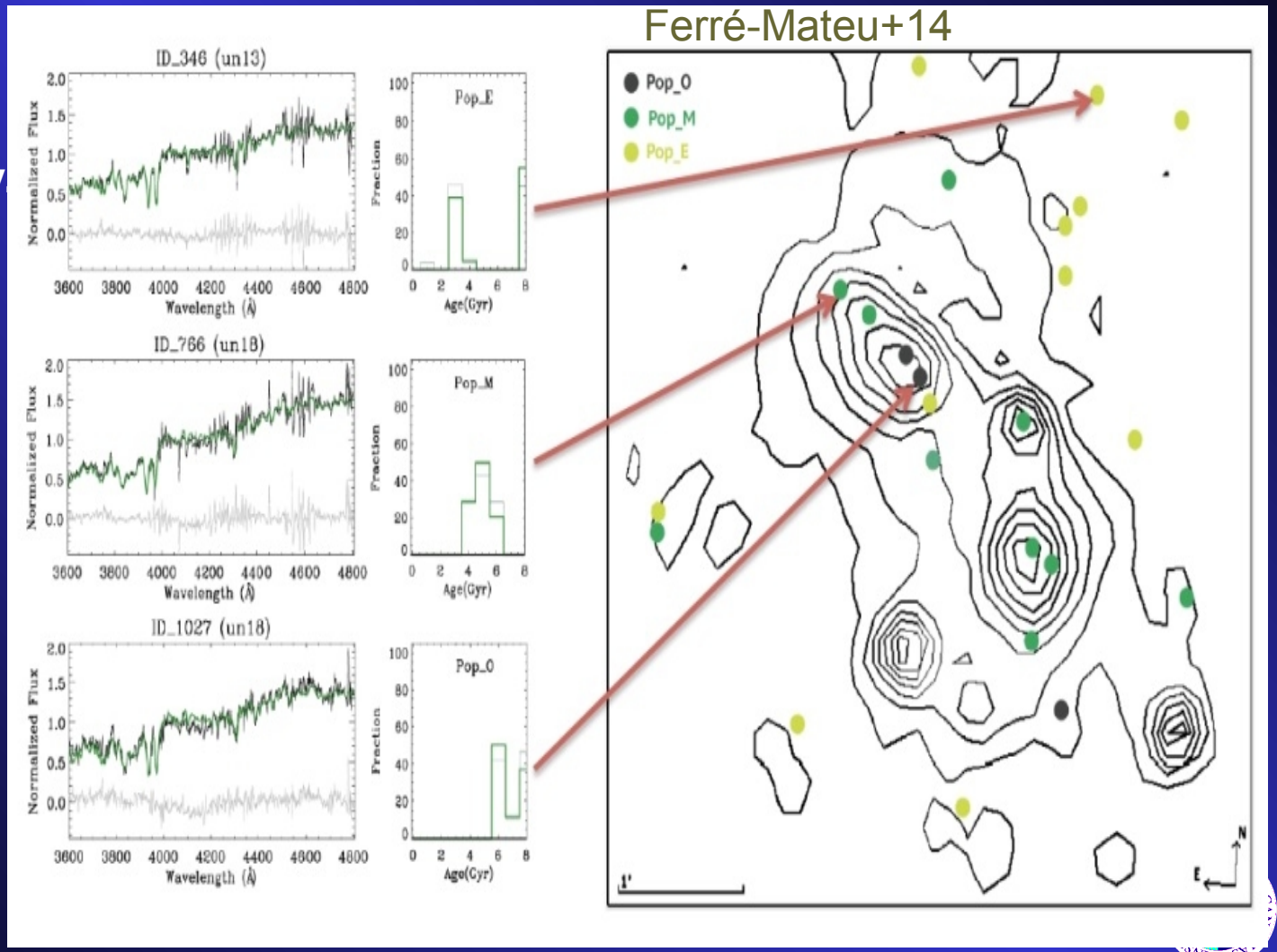
- V - [3.6] & V – [4.5]: Single-burst SSP models are in good agreement with Spitzer colours of massive ETGs.
- SSP models do not match low-mass galaxies: the presence of younger components redden their [3.6] – [4.5] colours.

No need for 1~Gyr like components (with large contribution of AGB stars) to fit massive ETGs. Only for low-mass ETGs are required.

Evolution with redshift

Detailed spectroscopic analysis of individual galaxies in a massive cluster at z~0.8 (similar to Coma):

- **Massive galaxies are found in the denser regions evolving passively. Their lower mass counterparts are located on the cluster perifery and their full spectrum-fitting show more extended SFHs.**
- **Their line-strengths show abundance patterns already similar to Coma**

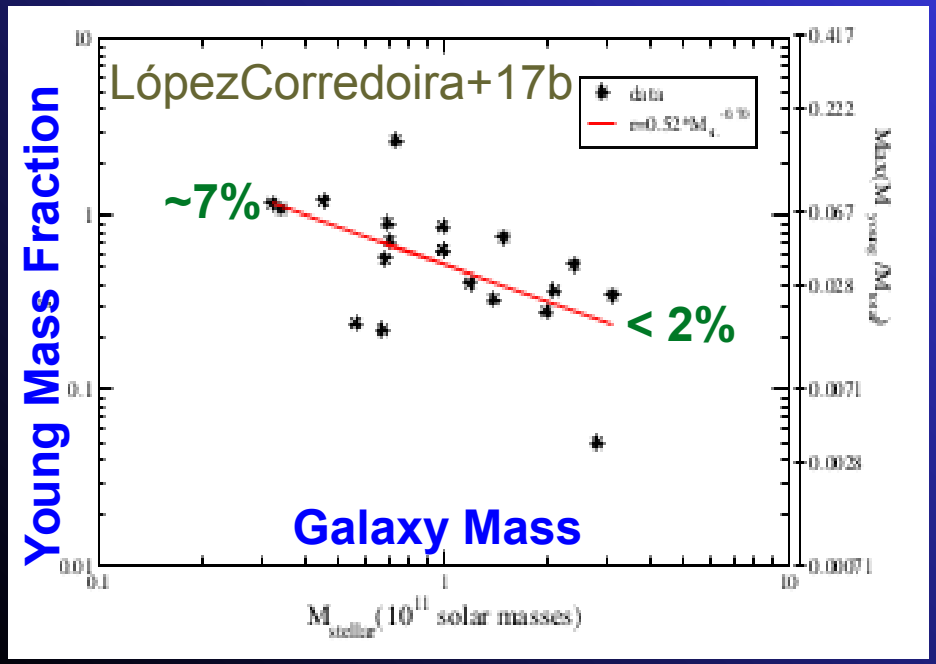


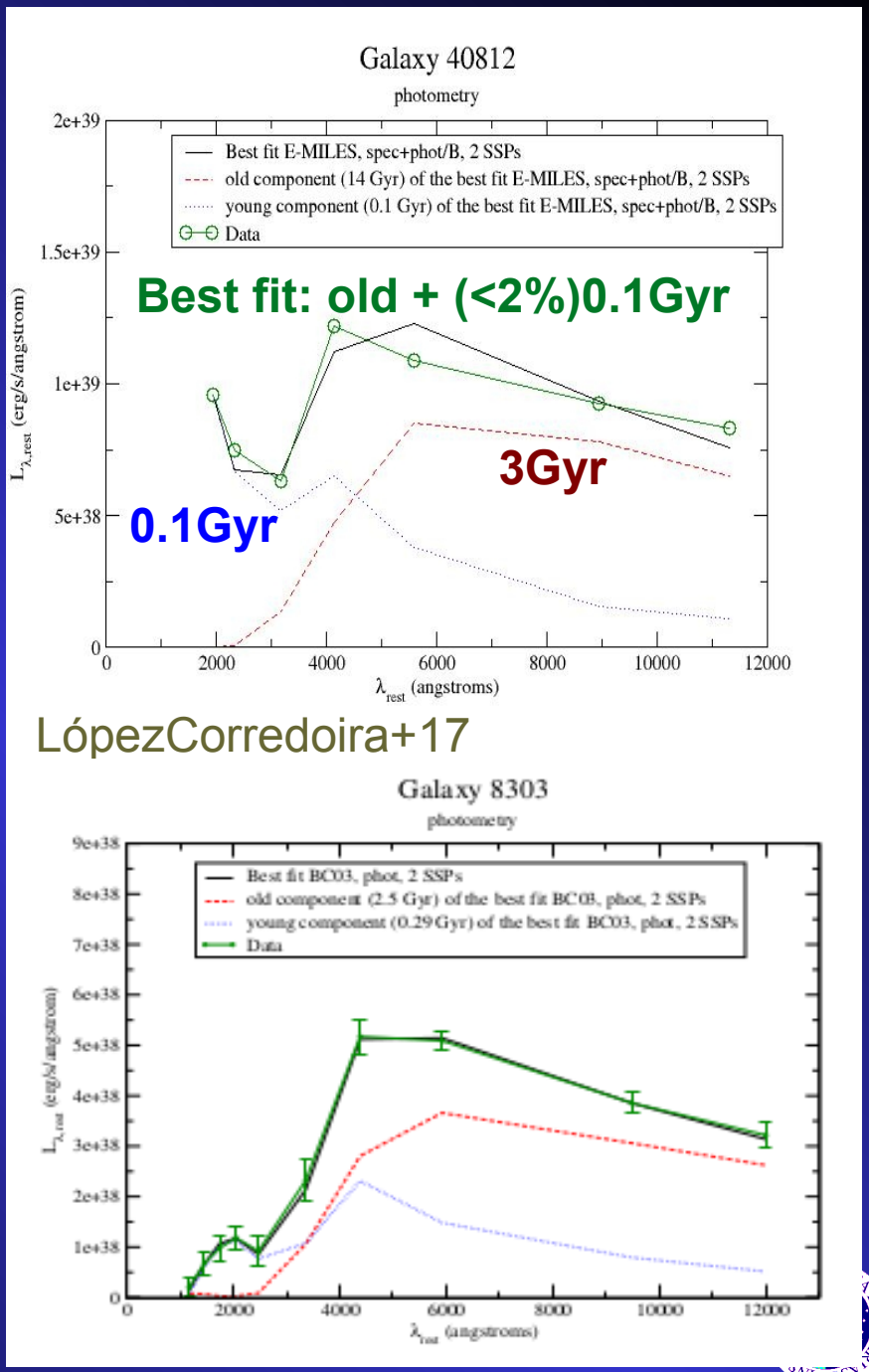
Evolution with redshift

Luminous red galaxies at z~3:

SED fitting: 3Gyr + 0.1-2%(~0.1Gyr) (similar to nearby ETGs, consistent with residual SF)

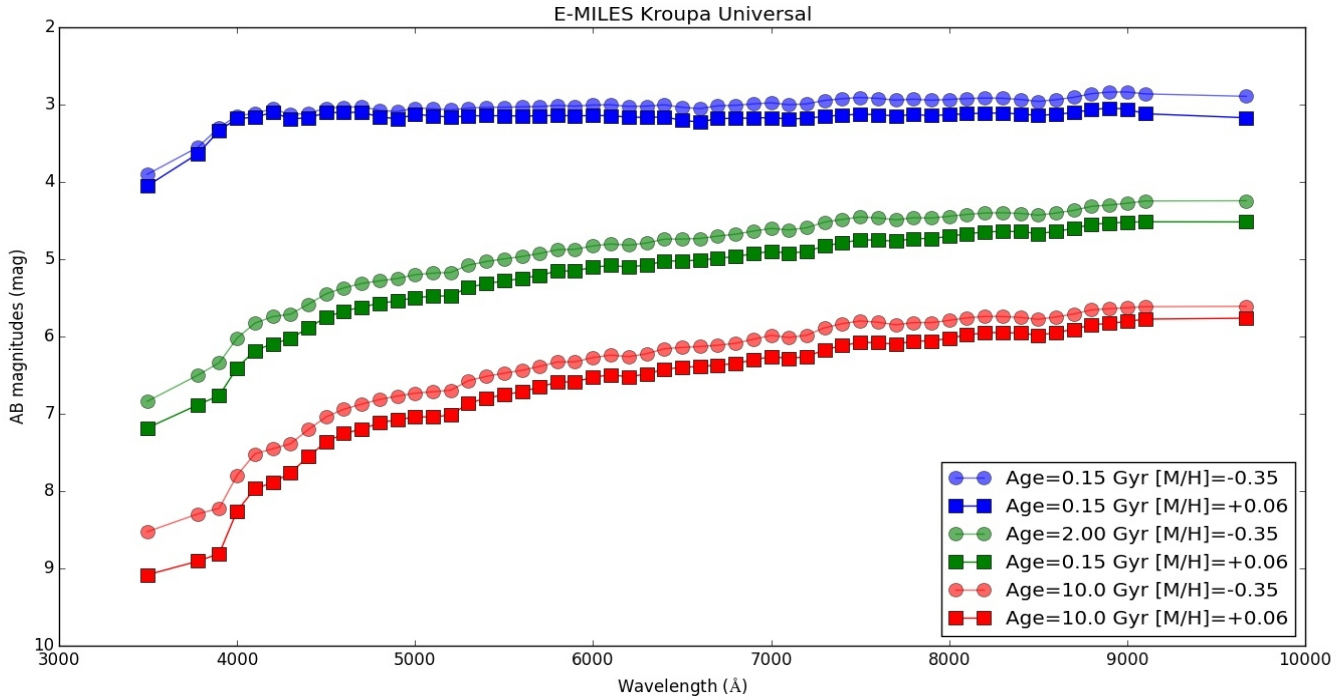
Downsizing already present at z~3





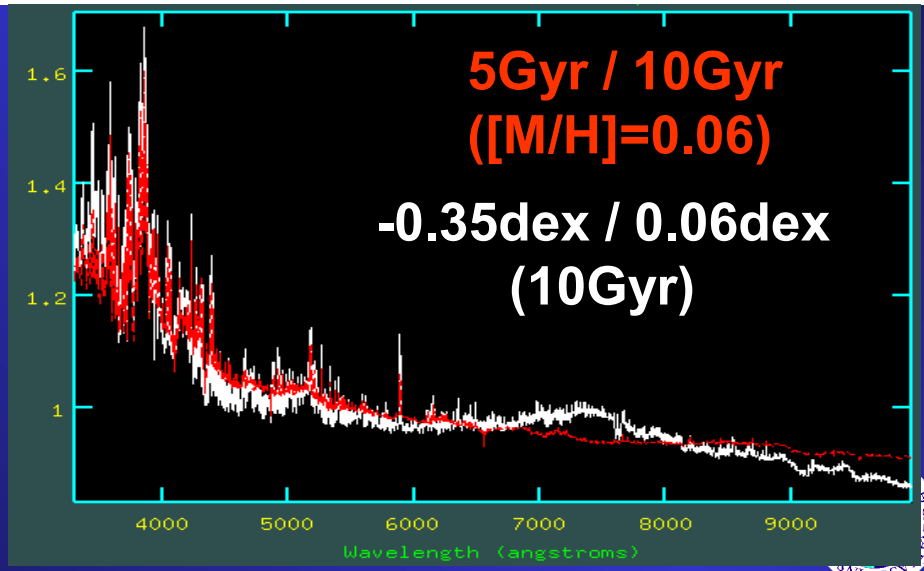
J-PAS filters

[M/H]
&
Age

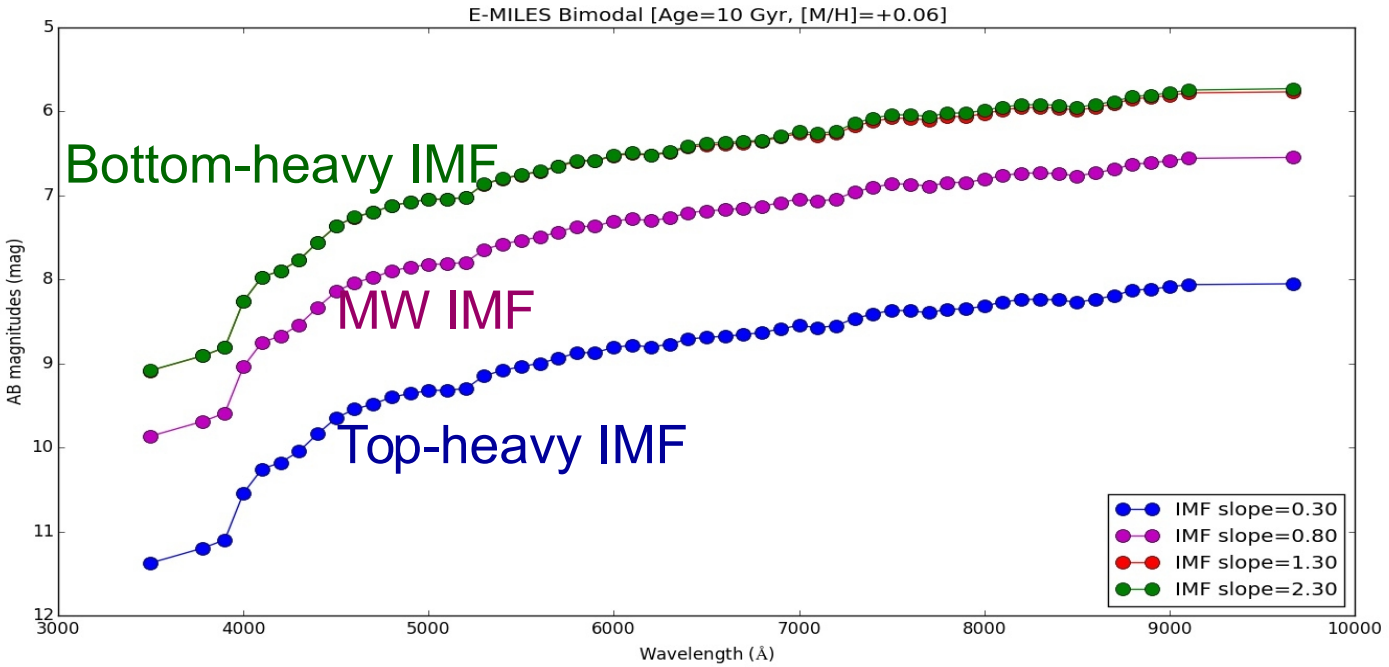


Spectral ratios:

Main challenge: disentangling the age/metallicity degeneracy by means of J-PAS spectro-photometric fitting technique (see PhD thesis of L. Díaz Garcia)

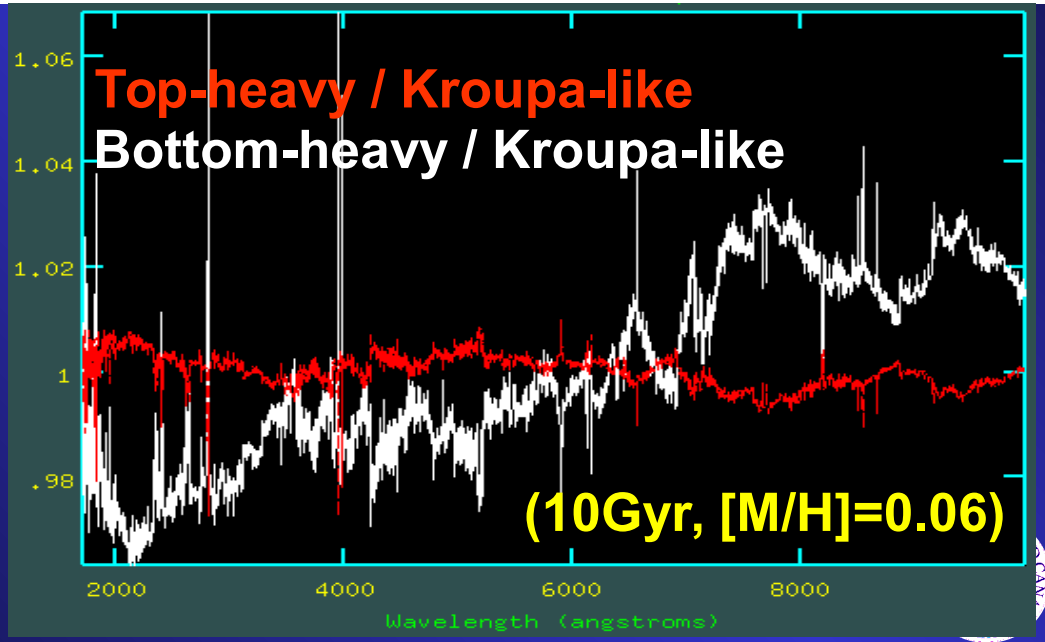


IMF



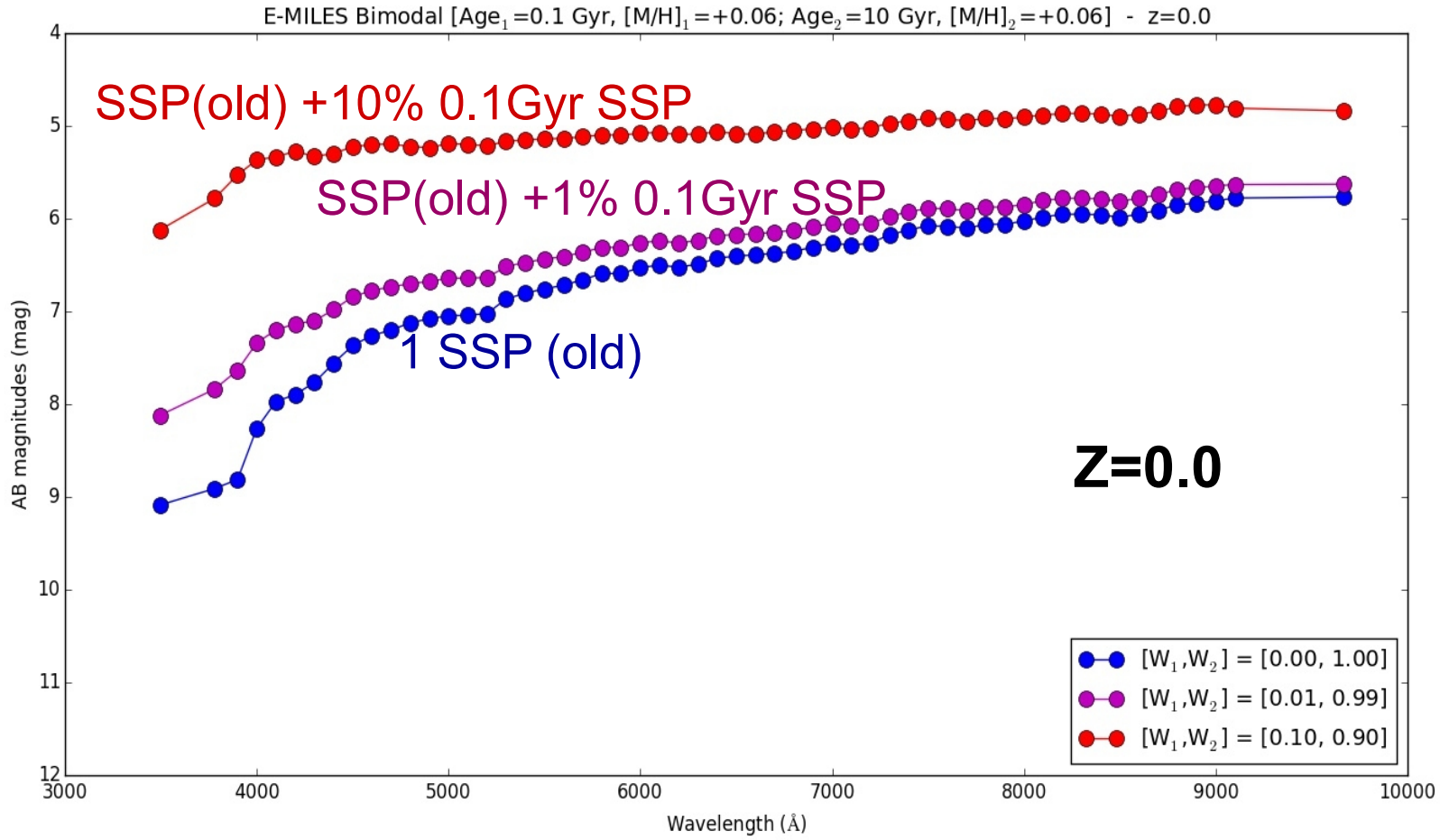
Spectral ratios:

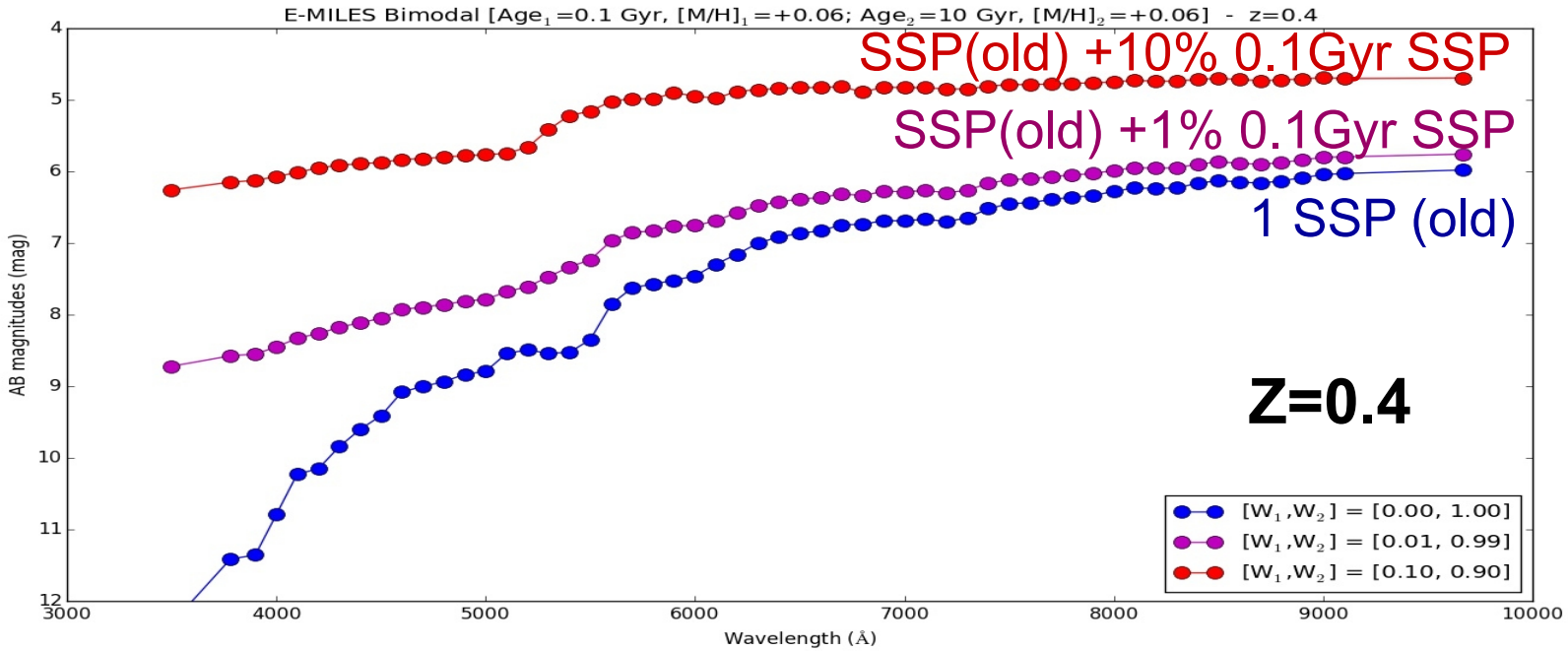
Bottom-heavier IMFs with slopes above 2 (Kroupa=1.3), like those of ETGs (giant Es) with σ~250km/s can be distinguished from those with σ~100km/s (MW-like)

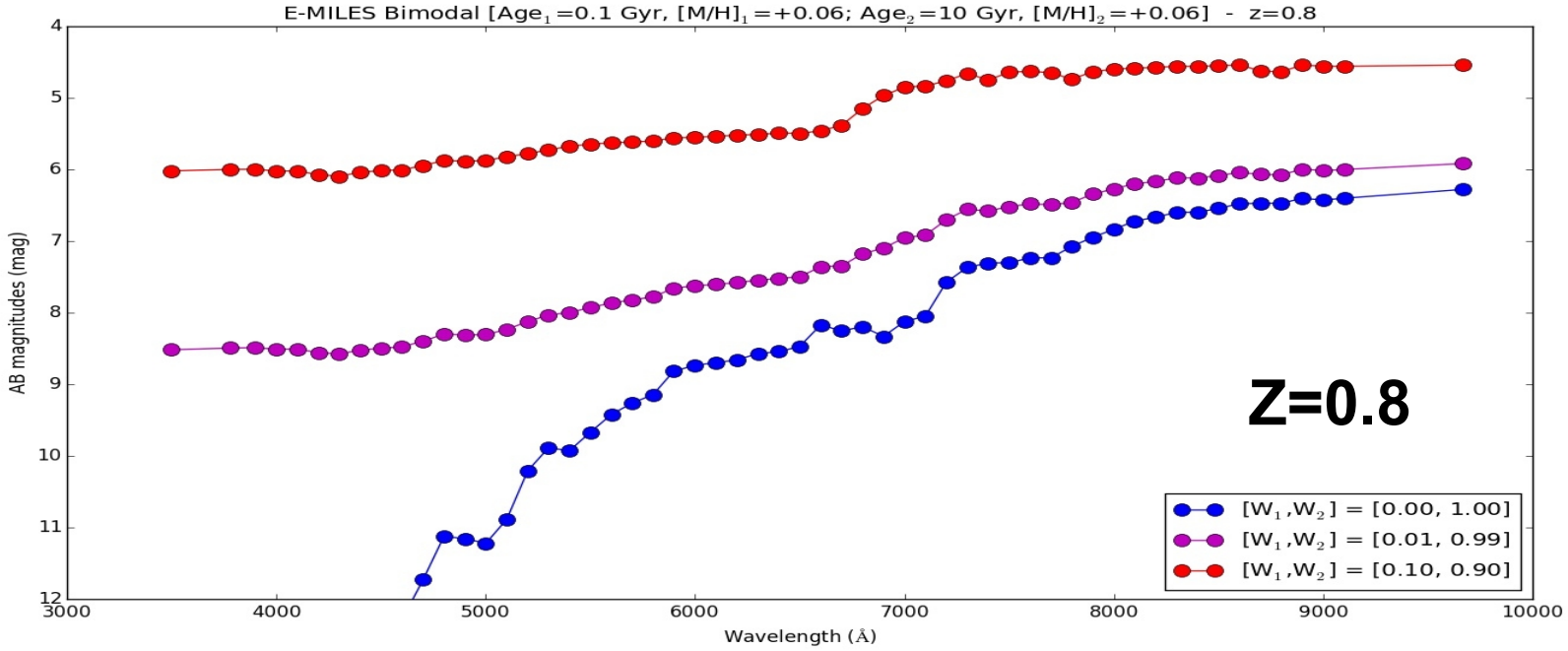


Are the J-PAS filters sensitive to these small contributions from young stellar components that go unnoticed in the optical range?

- **At z=0 only the very bluest filters are sensitive to young contributions >1%**




E-MILES Bimodal [Age$_1$ =0.1 Gyr, [M/H]$_1$ =+0.06; Age$_2$ =10 Gyr, [M/H]$_2$ =+0.06] - z=0.4
SSP(old) +10% 0.1Gyr SSP
SSP(old) +1% 0.1Gyr SSP
1 SSP (old)
Z=0.4
[W$_1$,W$_2$] = [0.00, 1.00]
[W$_1$,W$_2$] = [0.01, 0.99]
[W$_1$,W$_2$] = [0.10, 0.90]
AB magnitudes (mag)
Wavelength (Å)


E-MILES Bimodal [Age$_1$ =0.1 Gyr, [M/H]$_1$ =+0.06; Age$_2$ =10 Gyr, [M/H]$_2$ =+0.06] - z=0.8
Z=0.8
[W$_1$,W$_2$] = [0.00, 1.00]
[W$_1$,W$_2$] = [0.01, 0.99]
[W$_1$,W$_2$] = [0.10, 0.90]
AB magnitudes (mag)
Wavelength (Å)

Summary: results from extending the spectral ranges

- The UV is extremely sensitive to very small (< 1%) contributions from stellar populations with ages < 1Gyr.
- Massive ETGs are well fitted with single-burst like old stellar populations all the way from the Near-UV to 5μ. Smaller ETGs show in general more extended SFHs.
- Tiny mass fractions of 0.1-0.5% of stellar components with ages 0.1-0.5Gyr are required on the top of a dominant old stellar population to be able to fit both the colours and line-strengths in the UV. Such contributions are fully consistent with residual SF.
- Similar result holds for luminous red galaxies out to z~3.
- J-PAS filters:
  - Recovering the IMF and breaking the age/metallicity degeneracy is possible but requires very accurate photometry and state-of-the-art spectro-photometric fitting codes
  - J-PAS filters are particularly suitable for disentangling tiny young stellar components for objects in the redshift regime above 0.2.